ALASKA DEPT OF
ENVIRONMENTAL CONSERVATION

UNITED STATES COAST GUARD
SEVENTEENTH DISTRICT

U.S. EPA, REGION 10
ALASKA OPERATIONS OFFICE

In Situ Burning Guidelines for Alaska

Revision 1

March 22, 2001

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Tables and Figures

Glossary

Controlled burn: Combustion that is started and stopped by human intervention.

Complex terrain: Land that rises more than 10 percent of the atmospheric mixing layer height, where the smoke plume becomes level, as predicted by the National Weather Service or reported by smoke observers.

Flat terrain: Waterbodies and land that rises less than 10 percent of the mixing layer height where the smoke plume becomes level, as predicted by the National Weather Service or reported by smoke observers.

In situ burning: Combustion of oil on the surface where it spilled. "In situ" is Latin for "in place." Excludes well control, waste disposal, burning of oily vegetation, and adding a burning agent.

$PM_{2.5}$: Particulate matter with diameter of 2.5 microns or less.

PM_{10}: Particulate matter with diameter of 10 microns or less.

Public, human population, people: One or more persons who are not spill responders under the control of the Unified Command and a spill-specific worker safety plan.

Safe distance: Downwind from a fire, the greatest radius at which $PM_{2.5}$ emissions near ground level diminish to 1-hour concentrations equal to their National Ambient Air Quality Standard concentrations averaged for 24 hours or less.

Site safety plan: Incident-specific document for response worker protection that addresses the in situ burning operation, follows 29 CFR 1910.120 OSHA regulations, and is signed by the responsible party or the response action contractor. May also follow the National Response Team Science and Technology Committee's 1997 "Guidance for Developing and Site Safety Plan for Marine In Situ Burn Operations," and a plan in compliance with 18 AAC 75.425 (e)(1)(c), Alaska regulations for oil spill contingency plans' safety plans.

How to Use *In Situ Burning Guidelines for Alaska*

The document is guidance for federal and state on-scene coordinators.

- To learn this document's regulatory background, see Section 1.
- For technical background that supports the guidelines, see Sections 2, 3 and 4.
- The general guidelines for safe distances are described in Section 3 and Table 4.
- Cook Inlet and North Slope alternative guidelines for safe distances are described in Section 3 and Table 5.
- Public notifications, as conditions of authorization, are described at the end of Section 3 and in Table 7.
- The responsible party's application form to conduct in situ burning is provided following the background discussions.
- The federal and state on-scene coordinators' authorization guidelines for in situ burning are provided in the "On-Scene Coordinators' Review Checklist."

Background and Technical Information

1. INTRODUCTION

The Alaska in situ burning guidelines are used by the Alaska Department of Environmental Conservation, United States Coast Guard, and U.S. Environmental Protection Agency on-scene coordinators to authorize an emergency in situ burn of oil. To receive authorization, an applicant completes the “Application and Burn Plan” form found in this document and submits it to the on-scene coordinators in the Unified Command. The on-scene coordinators review the application in four steps before authorizing a burn. They may authorize burning when: mechanical containment and recovery by themselves are incapable of controlling the oil spill (Step 1), burning is feasible (Step 2), and the burn will lie a safe distance from human populations (Step 3). The authorization (Step 4) may include conditions designed to protect the public. The on-scene coordinators’ review checklist is provided in this document.

Among the guidelines are distances that should separate human populations from the burn to protect the public health. For example, on flat land and on water within 3 miles of shore, the on-scene coordinators, working within the Unified Command, may authorize burning 3 miles or more upwind of human populations. The on-scene coordinators may also authorize burning on marine water that is 3 miles or more from shore and 1 mile or more upwind from populated areas.

The “safe distances” are designed to meet the most recent state and federal air quality public safety regulatory standards in populated areas. A computer model has predicted the greatest downwind distance at which the smoke plume’s particulate matter of 2.5 microns or less in diameter ($PM_{2.5}$) diminishes to 65 micrograms per cubic meter averaged over one hour at ground level in flat terrain. At that distance, concentrations of soot and chemicals in the smoke are well below the National Ambient Air Quality Standards. In uninhabited areas, the safe separation distances are not necessary for burn authorization.

In some conditions in populated areas, the on-scene coordinators may authorize in situ burns without relying on computer predictions. The predictions apply only to distances beyond 1 kilometer and to flat terrain. However, the on-scene coordinators may authorize in situ burns closer to human populations and in hilly terrain, if their best professional judgment is that the smoke will not expose the public to emissions exceeding the National Ambient Air Quality Standard concentrations averaged over one hour.

Purpose and Scope

The *In-Situ Burning Guidelines for Alaska* aid the on-scene coordinators' decision process. The guidelines serve the following purposes:

- Protect public health from smoke emitted from emergency burns.
- Transfer the in situ burning authorization role to the DEC, USCG and EPA on-scene coordinators.
- Transfer the state open burn permit authorization role under 18 AAC 50.030 from the state air quality regulators to the state on-scene coordinator.
- Outline how to apply for, evaluate, and authorize in situ burning during an oil spill response.
- Incorporate most recent available criteria for human health protection.
- Provide a resource document for preparing in situ burning plans as part of the contingency plan process, regulated under 18 AAC 75.425(e)(3)(G)(iii), (iv), and (v).
- Provide a background for determining when to use the tool of in situ burning.

Applicability

These guidelines apply to any requests for emergency in situ burning to prevent the spread of spilled oil and minimize environmental damage. They apply to in situ burns on flat terrain, and on water in marine and inland areas. The guidelines also apply to burns on land in emergencies to reduce penetration and uncontrolled migration of the oil. The safe distances recommended in Section 3 apply to flat terrain, that is, water and land having a low relief relative to the height of the smoke.

The on-scene coordinators may also authorize in situ burning in complex terrain in some circumstances where safe distance rules are not developed. The authority is contingent on the on-scene coordinators' best professional judgment that ground-level $PM_{2.5}$ concentrations will remain below 65 micrograms per cubic meter 1-hour average in populated areas and that the other elements of these guidelines are followed. See Bronson (1998) and McGrattan et al. (1997) for considerations of complex terrain and multiple, simultaneous burns.

On-scene coordinators coordinate with landowners and stakeholders for in situ burns on land in flat or complex terrain.

The guideline document is neither an operational nor a tactical manual. It does not provide a contingency plan for an optional response tool, a site safety plan, nor an exhaustive literature review.

The guidelines are not applicable to the following burning activities: adding diesel as a burning agent, burning of thin films of oil which will not sustain ignition without a constant application of an independent ignition source (e.g., weed burner), disposing of oil and oiled material as waste, or burning oil wells.

Regulatory Background

In certain circumstances, the effectiveness of mechanical containment and removal is limited. In these circumstances, the use of in situ burning, alone or in conjunction with mechanical or chemical countermeasures, may minimize threats to public health, welfare, and the environment. The guidelines are the mechanism for the on-scene coordinators to authorize the use of in situ burning in response to oil discharges.

Under the National Oil and Hazardous Substances Pollution Contingency Plan (National Contingency Plan), the federal on-scene coordinator can authorize burning after obtaining concurrence from the U.S. Environmental Protection Agency and state representatives to the regional response team and, when practical, after consulting with the Department of the Interior and Department of Commerce representatives to the regional response team. From a federal perspective, "burning agents" must be authorized according to the provisions of the National Contingency Plan, 40 CFR Part 300.910. This provision enables the federal on-scene coordinator to "authorize" the application of burning agents when he or she believes it is appropriate, after key members of the Alaska Regional Response Team have been consulted and concur. Specifically the U.S. Environmental Protection Agency and state members must concur with the federal on-scene coordinator's recommendation to authorize the use of burning agents. Additionally, the federal on-scene coordinator must consult with the Department of the Interior and Department of Commerce Alaska Regional Response Team representatives when practical. The use of in situ burning is regulated by Subpart J of the National Contingency Plan, the Clean Air Act, the Federal Water Pollution Control Act as amended by the Oil Pollution Act of 1990, and State of Alaska law.

From a state perspective, in situ burning constitutes an open burn for which approval is required under Alaska air quality regulations (18 AAC 50.030). By following these guidelines, the state on-scene coordinator can approve in situ burning. The state's air quality regulations incorporate this document by reference in 18 AAC 50.030.

In Alaska, federal and state agencies consider applications for in situ burning under the Unified Plan and a unified command system that joins the federal and state on-scene coordinators in decision-making. The Unified Plan states that "whenever there is an incident involving more than one agency with jurisdiction, the Unified Command is implemented."

The on-scene coordinators will consult with the landowner and operator when in situ burning is requested. The consultation will be consistent with the exigencies of the emergency.

Updates in this Revision

This is Revision 1 of the *In Situ Burning Guidelines for Alaska.* It updates the Revision 0 guidelines that were incorporated into the Unified Plan in 1994. Revision 1 includes the following changes from Revision 0:

- Revision 1 is not a pre-approval under the NCP.
- The safe distances recommended between an in situ burn and human populations are refined. See Section 3.

- The "ISB Review Checklist" and "Application for ISB" in the 1994 guidelines are streamlined. The new forms are "Application and Burn Plan" and "Review Checklist."

- The new safe distance guidelines are based on the smoke plume's predicted concentrations of $PM_{2.5}$. The 1994 guidelines were based on PM_{10} concentrations. The change takes into account the new National Ambient Air Quality Standards for $PM_{2.5}$ that became effective in 1997. See Section 3.

- Revision 1 assumes that maintaining safe distances between human populations and harmful levels of $PM_{2.5}$ will also provide an adequate buffer to protect human populations from air toxics and all other byproducts of combustion.

- The new version of the smoke plume trajectory model, ALOFT-Flat Terrain version 3.04 for PC, distinguishes between flat, complex terrain, and water scenarios. This refinement is reflected in the new safe distance guidelines. See Section 3.

- Safe distance prediction uncertainty is expressed in graphs of mixing height and wind speed effects in McGrattan et al. (1997). Predicted distances are no longer multiplied by a factor of 2 to produce safe distance guidelines.

- Revision 1 considers the results of in situ burning studies reported in the proceedings of the International Oil Spill Conferences and the Arctic and Marine Oilspill Program Technical Seminars since 1994, the current in situ burning guidance of other Regional Response Teams, and recent guidance from the National Response Team. In Revision 1, the conditions of authorization of in situ burning include residue collection and visual monitoring of the smoke plume.

- Land in situ burning authorization is addressed.

- Discussions of the importance of in situ burning in Alaska and general issues of smoke, residues, and toxicology are updated and reduced.

2. OPERATIONAL CONSIDERATIONS

The in situ burning operations discussion in this section supports Steps 1 and 2 of the in situ burning application and review. In Step 1 the on-scene coordinators decide whether mechanical containment and recovery by themselves are capable of controlling the oil spill. Step 2 is a determination whether in situ burning is feasible under the spill circumstances.

In Situ Burning in Relation to Mechanical Recovery

When mechanical recovery is unfeasible or ineffective, removing oil from the water by in situ burning may provide significant protection for fish, wildlife, and sensitive environments, as well as commercial, subsistence, historic, archaeological, and recreational resources. In situ burning may (1) prevent the resources from coming into contact with spilled oil; (2) reduce the size of the spill and thus the amount of spilled oil affecting natural resources; (3) allow the environment to recover to the pre-spill state sooner; and (4) provide the most effective means to remove oil from water prior to shoreline impacts in broken ice conditions, in remote or inaccessible areas, or when containment and storage facilities are overwhelmed.

Optimal Conditions for Burning

Table 1 summarizes the optimal conditions for in situ burning. Oil thickness and emulsification have the greatest effects on ignition and burn efficiency. Most types of oil burn readily. However, the difficulty of establishing and maintaining slick thickness of lighter oils and achieving ignition of heavier oils make in situ burning less feasible for some oils, such as diesel and Bunker C.

Oil Thickness and Containment

Thicker layers of oil more readily ignite and sustain a burn. A minimum thickness of 2 to 3 millimeters of oil is usually required for ignition (ASTM 1997) regardless of oil type. The thickness necessary for successful ignition increases with weathering and viscosity of oils. For example, minimum ignitable thicknesses for Alaska North Slope crude oil are estimated at 1 millimeter for fresh, volatile crude; 2 to 5 millimeters for aged, unemulsified crude; and 5 to 10 millimeters for burnable emulsions (S.L. Ross 1997). Once the slick has been ignited, combustion is sustained as long as the slick maintains some minimum thickness, estimated to be about 1 millimeter (ASTM 1997).

Thicker layers of oil also burn more efficiently. The U.S. Environmental Protection Agency (1991) found that in a slick of 10 millimeters thickness, approximately 80 to 90 percent of the oil burned. In a slick of 100 millimeters thickness, approximately 98 to 99 percent of the oil burned.

Table 1
Optimal Conditions for Effective Burning of Alaska North Slope Crude Oil

Considerations	Conditions for Effective Burning
Oil thickness	Minimum 2 to 3 mm for ignition. Efficiency (percent of oil in the boom removed by burning) increases with increased thickness.
Emulsification	Less than 25% water content. Efficiency and ease of ignition decrease with increasing water content.
Weathering	Relatively fresh oil (less than 2 to 3 days of exposure) is best for ignition. Difficulty of ignition increases with further weathering. Weathering times may vary among crude oil types and weather conditions.
Wind	Less than 20 knots for ignition.
Waves	Waves impact boom effectiveness and combustion primarily by causing splash-over. Less than 3 ft in choppy, wind-driven seas is optimal (short-period waves, less than 6 seconds). Less than 5.7 ft in large swells is optimal (i.e., long-period waves, greater than 6 seconds).
Currents	Less than 0.75 knots relative velocity between the fire boom and the water is optimal.
Ice	Variable effects depending upon geometry. Where ice contains the oil and prevents it from spreading, the burn can remove a high percentage of the contained slick. Isolated floes may interfere with booming operations.

Adapted from Alyeska Pipeline Service Company, 1996.

In many situations, spilled oil is concentrated by containment to achieve the minimum thickness level. Fire-resistant boom contains oil best when deployed in a catenary mode and towed at speeds of less than 0.35 m/s (0.7 knots) (ASTM 1997). At greater speeds, oil is lost under the boom by entrainment.

Broken ice concentrations of approximately 8 tenths coverage or greater provide good containment for oil trapped between ice cakes and floes (Industry Task Group 1984). In broken ice conditions in Cook Inlet and on the North Slope, oil can be contained by the reduced area available for spreading, the cold surface waters, and the reduced influence of wind. During field tests conducted by Buist and Dickins (1987), broken ice “dramatically reduced” the spread of oil.

Solid ice on the North Slope can contain oil as follows (Industry Task Group 1984):

- Landfast sea ice provides barriers to the spread of oil spilled on or beneath it.

- During the solid-ice period, cold air temperatures, surface roughness, and snow limit the spread of oil and reduce evaporative losses, thus enhancing in situ burning operations.

- Oil on early spring ice accumulates in melt pools, and subsurface oil slowly migrates to the surface through brine channels and cracks.

- During freezeup, spilled oil becomes contained by new thin or slush ice.

Guenette and Sveum (1995) found that fresh crude and emulsions can be burned uncontained on open water. The wind-herding effect of the burn allows the slick to maintain sufficient thickness to burn at similar efficiencies to contained burns. The burning, uncontained emulsion slicks spread significantly less than the burning, uncontained fresh crude slicks.

Shorelines also sometimes serve as natural containment for oil for in situ burning (ASTM 1997).

Emulsification

Emulsification decreases ignitability, burn rate, and burn efficiency (Buist et al. 1997). In a series of small-scale test burns, Buist (1989) concluded that for a given thickness of oil, ignition times increased only slightly with weathering but increased dramatically with emulsification.

Although not enough data are available to determine the specific emulsification percentage that limits ignition, indications are that oil containing less than about 25 percent water will burn, while emulsions containing 70 percent water cannot be ignited (ASTM 1997).

Alaska Clean Seas conducted test burns on weathered, emulsified crude oil (Buist et al. 1996, 1997). The tests showed that Alaska North Slope crude cannot be ignited at emulsifications greater than 25 percent, although the results varied widely among oil types (Buist et al. 1995b). Endicott crude emulsions of up to 25 percent water burned well, even with weathered oil. Emulsions of Point McIntyre crude and IF-30 fuel oil, however, were difficult to burn, even with no weathering.

The ADIOS model (NOAA 1994) and S.L. Ross (1997) describe emulsification rates of oils.

Weathering

Weathering (i.e., evaporation) decreases the ignitability and efficiency of in situ burns (Buist et al. 1996). Hossain and MacKay (1981) found that weathering resulted in the loss of volatile compounds, more difficult ignition, and slower combustion, but in some cases, a higher proportion of oil burned. Weathering up to about 20 percent appeared not to affect the burn efficiency of crude oil. Between 20 and 35 percent, weathering increased burn efficiency, but beyond 35 percent efficiency declined.

Waves

In test burns, wave energy increased the burn rate of thicker unemulsified slicks (10 to 20 millimeters) of fresh and weathered Alaska North Slope crude. However, waves had little effect on the burn rate of thinner slicks (2 to 5 millimeters). Although waves decreased the burn rate of emulsions of 10.3 percent evaporated Alaska North Slope crude, they had little effect on the burn rate for 29.1 percent evaporated emulsions (Buist et al. 1997).

Burn Volumes

Burn rate is relatively independent of physical conditions and oil type. Oil burns at a rate of about 0.07 gallons/square foot/minute, or about 100 gallons/square-foot/day (ASTM 1997). This means that a single 500-foot fire boom, positioned in a U configuration to intercept a spill, provides enough burn area to sustain a burn rate of 15,000 barrels per day. Three such U configuration booms working in a collection-relocation-and-burn mode could burn approximately 8,000 barrels of oil during a 12-hour period, with only one U configuration burning at a time (Allen and Ferek 1993).

Residues

The environmental advantages of in situ burning outweigh the potential environmental drawbacks of burn residue, including the possible environmental harm if the burn residue sinks. Therefore, the on-scene coordinators do not consider the potential impacts of burn residue when deciding whether to authorize an in situ burn. Nevertheless, the responsible party or applicant is required to have a plan for residue collection.

Volume and Chemical Composition. The volume of residues produced by in situ burning is much lower than the original volume of the oil (Table 2), and is altered in chemical composition and physical properties from the oil. During a burn, the lighter, lower-boiling-point hydrocarbons are eliminated, while the heavier, higher-boiling-point hydrocarbons are concentrated in the residue. Trudel et al. (1996) found that the majority of burn residues are composed of non-volatile compounds with boiling points greater than 538°C. Burn residues from crude oils contained no volatiles with boiling points less than 204°C; all contained some portion of the medium-volatility compounds with boiling points between 204°C and 538°C. Burn residues are therefore less toxic than the parent oils, because the lower-boiling-point volatiles such as benzene, naphthalene, and benzopyrenes are absent (S.L. Ross 1997).

Table 2
Residue Produced During the Newfoundland Offshore Burn Experiment

Variable	Burn 1	Burn 2
Volume of oil discharged (m^3)	48.3	28.9
Residue in fireproof boom after the burn (m^3)	0.2 (max.)	0.1 (max.)
Residue in backup boom after the burn (m^3)	0.2 (max.)	0.3 (max.)
Burn efficiency	>99%	>99%
Density (g/mL at 15°C) (density of sea water is 1.025)	0.9365	

Data from Fingas et al., 1994a.

Physical Properties. Burn residues are more dense and viscous than oil. During two test burns with Alaska North Slope crude oil, one with fresh, unweathered oil and the other with weathered, emulsified oil, the residues in both cases sank after the residue had cooled (Buist et al. 1995a and b). Table 3 lists the densities of Alaska North Slope crude oil residues after several test burns.

Table 3
Characterization of Residues from Laboratory Test Burns of Alaska North Slope Crude

	Thickness of Oil Slick		
Variable	5 cm	10 cm	15 cm
Burn efficiency	84.9%	91.6%	90.9%
Density (in g/cm^3) at 15°C (density of normal sea water is 1.025)	1.025	1.075	1.045

Adapted from Tables 4 and 5, Buist et al., 1995.

Residues from in situ burns vary greatly in consistency. Tests on Alaska North Slope crude oil produced residues ranging in consistency from a “semi-solid not unlike cold roofing tar” for fresh, unweathered oil, to residue in the form of a “brittle solid” for weathered, emulsified oil (Buist et al. 1995a and b). The 15,000- to 30,000-gallon test burn during the *Exxon Valdez* spill produced about 300 gallons of “stiff, taffy-like residue that could be picked up easily” (Allen 1990). Emulsion residues can be less viscous and more difficult to recover than residues from fresh crude. Floating, tar-like residue be removed manually with sorbents, nets, or other similar equipment. However, recovering the less-burned residue from emulsion burns, which can include unburned oil and emulsions, may require a large pump (Guenette and Sveum 1995). Residues of some oils, including Alaska North Slope crude, may sink as they cool, even in sea water.

Monitoring and Trial Burns

In situ burn operations incorporate constant visual monitoring of the smoke plume's behavior. U.S. Environmental Protection Agency and Alaska Department of Environmental Conservation representatives monitor the smoke plume of inland burns by aerial observation. The Alaska Department of Environmental Conservation representatives monitor the smoke plume of coastal in situ burns. The burn operations team also visually monitors the smoke plume for all in situ burns. The burn may be stopped if the plume contacts or threatens to contact the ground in a populated area. The predictive model results and visual monitoring are applied in lieu of air sampling.

The federal and state on-scene coordinators may authorize a trial in situ burn of one fire-resistant boom full of oil to confirm anticipated plume drift direction and dispersion distances downwind before authorizing the proposed burn.

Safety of Personnel

A site safety plan for in situ burning is required. Occupational Safety and Health Act regulations (29 CFR 1910.120) specify that employers are responsible for the health and safety of employees in response situations. Generally, the in situ site safety plan is an appendix to an umbrella site safety plan covering the entire spill response (NRT 1997b). The combination of the general site safety plan and the appendix site safety plan for in situ burning must include the elements listed in 29 CFR 1910.120(b)(4).

Incorporated here by reference for guidance is "Guidance for Developing a Site Safety Plan for Marine In Situ Burn Operations," written by the National Response Team's Science & Technology Committee (1997a). Alyeska Pipeline Service Company's "Supplemental Information Document: Burning as a Response Tool" (1996) also provides suggestions.

Safety concerns associated with in situ burning include the following:

- **Fire hazard.** In situ burns are monitored to ensure that fire does not spread to adjacent combustible material. Care is taken to control the fire and to prevent secondary fires. Personnel and equipment managing the process are protected.

- **Ignition hazard.** Ignition of the oil slick receives careful consideration. Involvement of aircraft for aerial ignition with gel or other ignition methods is coordinated. Weather and water conditions are kept in mind, and safety distances are set and adhered to.

- **Extinguishing and controlling the burn.** An in situ burn on water may be extinguished by increasing the tow speed so that oil is entrained in the water, by slowing down to reduce the rate at which the boom encounters oil, or by releasing one side of the oil containment boom. In the test burn during the *Exxon Valdez* spill, Allen (1990) noted that the area of the burning oil was easily controlled by adjusting the speed of the towing vessels.

- **Vessel safety.** In situ burning at sea involves several vessels working in relatively close proximity to each other. Vessels and crews working in these conditions have practiced the techniques involved with in situ burning.

- **Other hazards.** Training and safety guidelines are a part of all in situ burning operations. Working under time constraints may impair judgment or increase the tendency to attempt costly shortcuts. In Alaska, personnel may be exposed to extreme cold. Personnel may also be exposed to extreme heat from the fire.

3. SAFE DISTANCE

The safe distance discussion in this section supports Step 3 of the in situ burning application and review. In Step 3 of the decision-making process, the on-scene coordinators determine whether the burn lies at a safe distance from human populations. In situ burning is not authorized if it does not meet public health regulatory standards. The on-scene coordinators may use Table 4 for general safe distance guidance. They may use Table 5 in place of Table 4 in Cook Inlet and on the North Slope. Step 4 is the authorization to burn. Authorization may include conditions that will help to protect human health.

The Public Safety Criterion

The safe distance separating human populations from in situ oil burns is the downwind radius from the fire at which smoke $PM_{2.5}$ concentrations at the ground diminish to 65 micrograms per cubic meter averaged over one hour. The safe distance guidelines are based on the predictions of a computer model, ALOFT-Flat Terrain model 3.04. The safe distance meets the National Ambient Air Quality Standards for particulate matter in flat terrain and is also used as the indicator that human populations will not be exposed to unsafe levels of all other smoke components.

Computer modeling was used so that real-time air sampling of the smoke plume is not necessary during an in situ burn. However, visual monitoring of the plume is required. On-scene coordinators may require air sampling for particulate matter during longer in situ burns. Fifty-six scenarios in Cook Inlet and the North Slope were modeled by the program, and the worst-case predictions were used to develop the safe distances. Incorporated here by reference is "In Situ Burning Safe Distance Predictions with ALOFT-FT Model" (Bronson 1998), which explains how the safe distances were predicted.

$PM_{2.5}$ reflects the size of particulates that pose the greatest human health hazard. The National Response Team noted that if the particulate matter standard is "exceeded substantially, human exposure to particulates may be elevated to a degree that justifies terminating the burn. If particulate levels are generally below the limit, with only minor transitory incursions to high concentrations, there is no reason to believe that the population is unacceptably exposed above the accepted National Ambient Air Quality Standard for the burn" (NRT 1995). Furthermore, safe $PM_{2.5}$ concentrations indicate safe concentrations of other emissions (Bronson 1998).

The factor of 2 that was applied to the downwind distance predictions in the 1994 in situ burning guidelines (ARRT 1994) is replaced as the means to incorporate uncertainty in the safe distances. Uncertainty in the predictions is now shown in the diagrams introduced by McGrattan et al. (1997) and discussed by Bronson (1998).

Safe Distance in Populated, Flat Terrain

The on-scene coordinator determines whether the flat terrain safe distance guidelines apply. Among the conditions of authorization is that the in situ burn lies a safe distance from human populations. With a topographic map, the on-scene coordinator finds the rise of the terrain downwind of the fire. With a phone call to the National Weather Service, the on-scene coordinator learns the predicted atmospheric mixing layer height. Where the mixing layer height is less than 10 times the rise of the land above the fire, the area is considered complex terrain; safe distance rules are not available there. Where the expected mixing layer height exceeds 10 times the topographic rise above the fire, the area is considered flat terrain. In flat terrain, the on-scene coordinator considers the safe distance recommendations outlined in this section.

Table 4 lists the general safe distances separating an in situ burn and downwind, populated areas in flat terrain. Figures 1 through 4 show bird's-eye and cross-sectional views of the safe distances.

Table 4
Safe Distances Between In Situ Burns
and Downwind Human Populations in Flat Terrain

Location of Fire	Green Zone	Yellow Zone	Red Zone
Flat terrain on land	>3 miles	1 to 3 miles	<1 mile
Water <3 miles from shore			
Water >3 miles from shore	>1 mile	not applicable	<1 mile

On water more than 3 miles from shore, the green zone safe distance is 1 mile from the public. On land or on water less than 3 miles from shore, the green zone safe distance is 3 miles from the public. Burning at a green zone safe distance from the public is acceptable following Level 1 public notification.

The yellow zone distance extends from 1 to 3 miles downwind of an in situ burn, and within 45 degrees of the smoke plume, when the burn is on land or on water within 3 miles of shore. The quadrant shape of the zone protects people from smoke subjected to minor wind shifts. The on-scene coordinators may authorize burning following Level 2 and Level 3 public notifications, warning, and sheltering in place or evacuation.

The red zone distance is within 1 mile of any in situ burn and within 45 degrees of the smoke plume. The on-scene coordinators may authorize burning in the red zone following public notifications, warnings, and sheltering in place or evacuation, and if the on-scene coordinators' best professional judgment supports the expectation of $PM_{2.5}$ less than 65 micrograms per cubic meter 1-hour average in populated areas.

The red zone radius takes into account that the risk of smoke exposure becomes greater close to the fire. In addition, the ALOFT model does not predict the behavior of smoke close to the fire before it lofts. The red zone downwind boundary also lies downwind of the expected in situ burn operations site safety area. For example, a 1,000-foot radius around an in situ burn of oil in a fire boom may be designated as the worker site safety zone by the site safety officer.

The Table 4 rules apply only in the following situations:

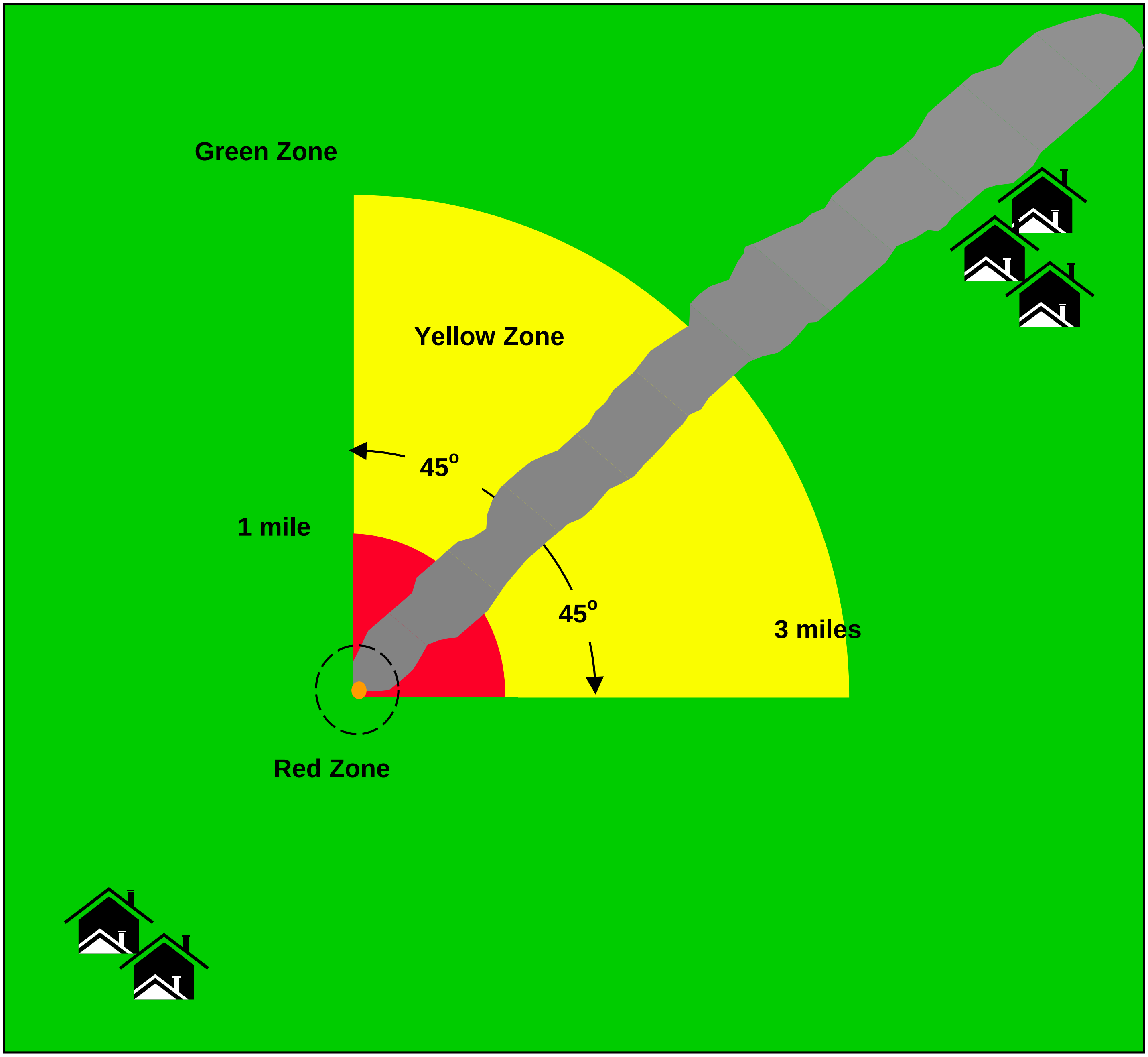
- In the vicinity of human populations
- For a burn of any size from a single source
- For simultaneous burns less than 100 yards apart

The Table 4 rules do not apply in the following situations:

- In unpopulated areas
- In situ burns less than 3 miles upwind of terrain that rises more than 10 percent of the mixing layer height
- For simultaneous burns more than 100 yards apart

Figure 1

Zones for In Situ Burns on Populated Flat Land, and on Water Within 3 Miles of Shore



The dashed circle shows an example of a 1,000-ft radius site safety zone for workers, determined under a separate site safety plan.

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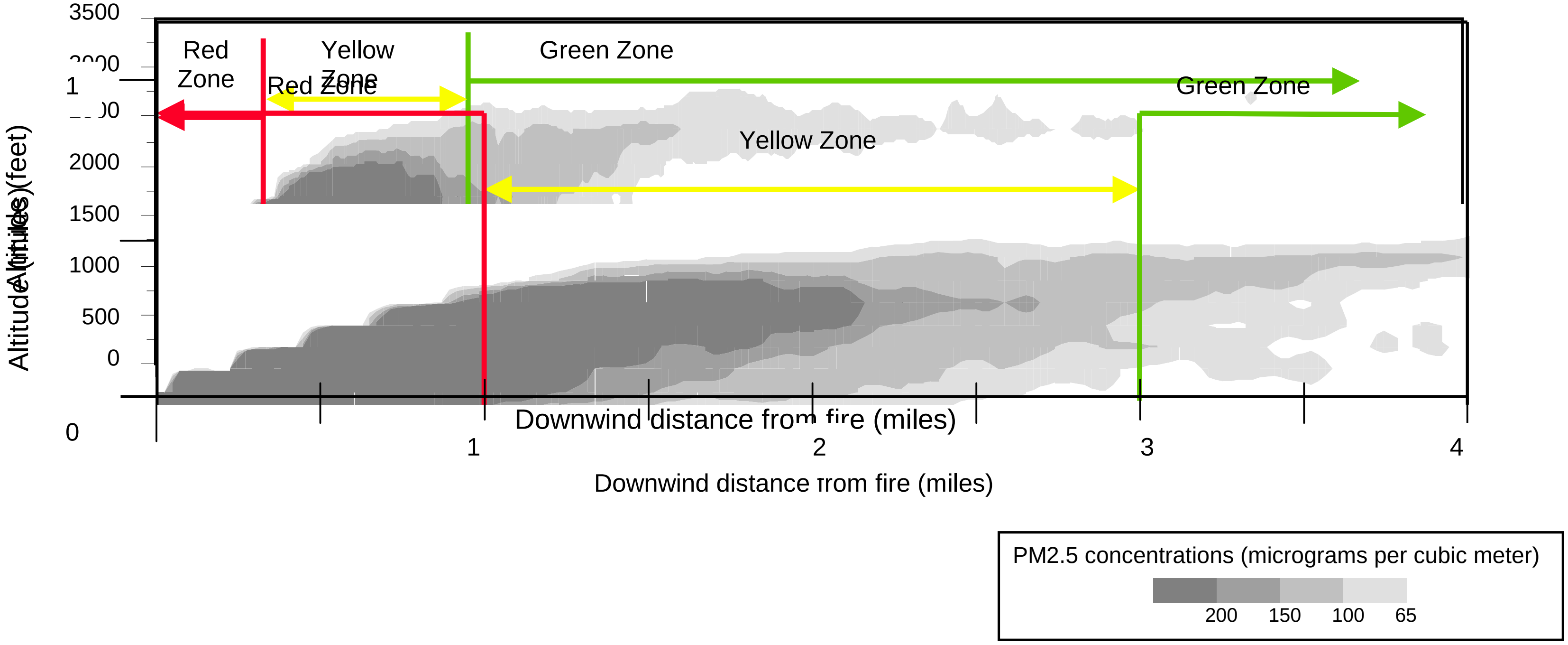
Figure 2. Example of zones for an in situ burn over land or on water within 3 miles of shore.

ALOFT model projection for a burn of 5,000 square feet of oil in Cook Inlet during the summer.



PM2.5 concentrations (micrograms per cubic meter)

200 150 100 65

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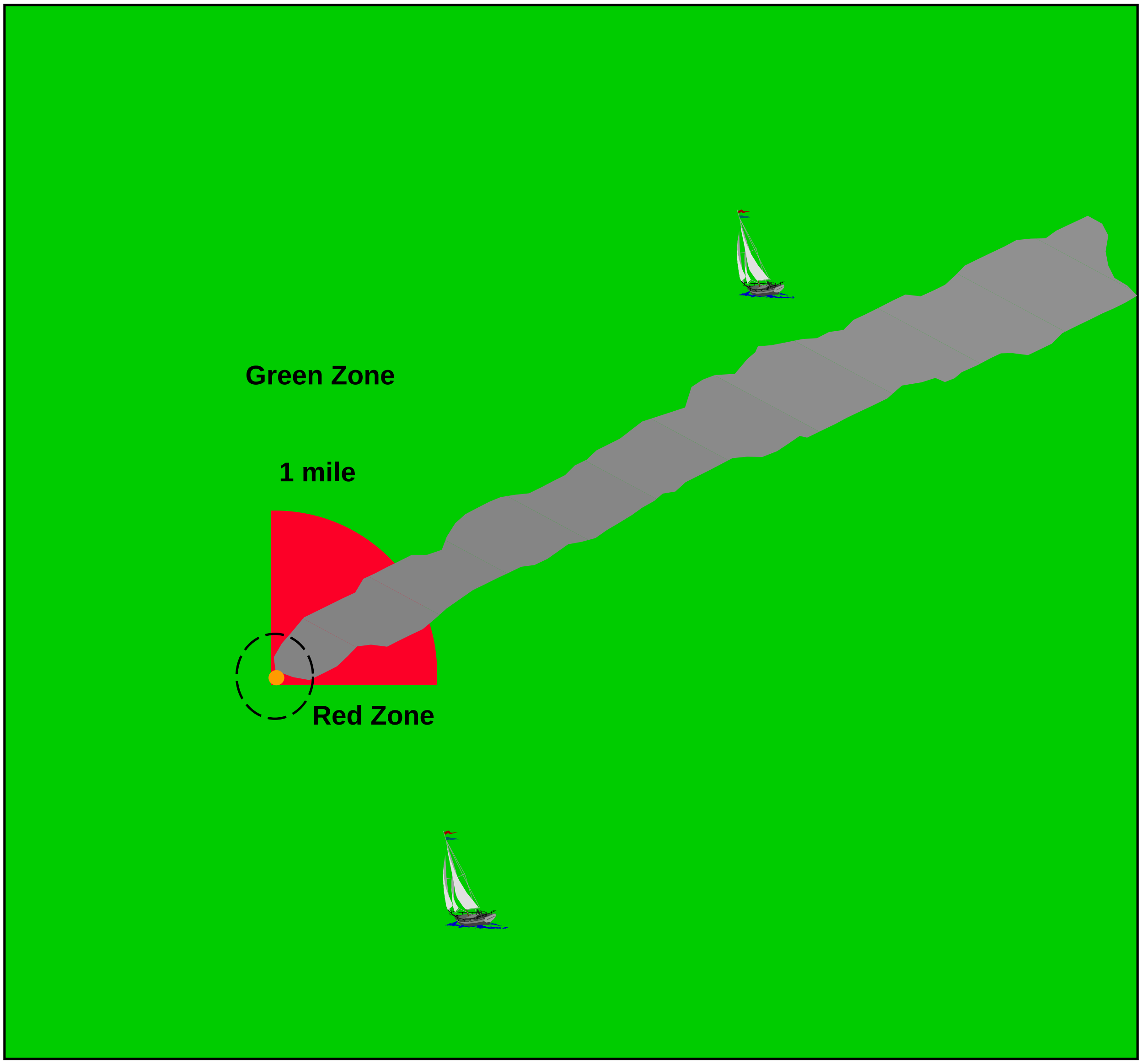
Figure 3

Zones for In Situ Burns on Water more than 3 Miles from Shore



The dashed circle shows an example of a 1,000-ft radius site safety zone for workers, determined under a separate site safety plan.

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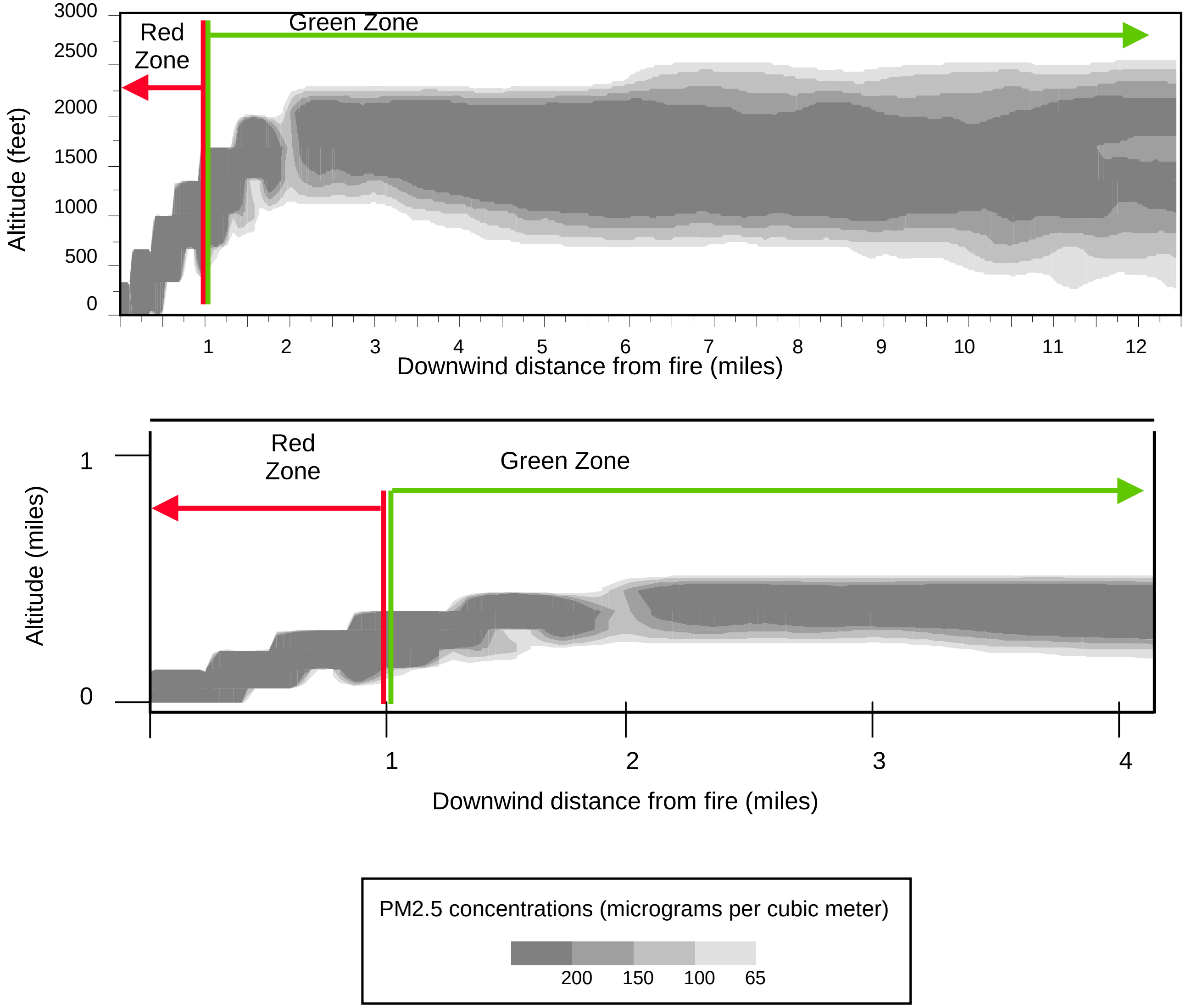
Figure 4. Example of zones for an situ burn on water at least 3 miles from shore.

ALOFT model projection for a burn of 5,000 square feet of oil in Cook Inlet during the summer.



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Authorization in Cook Inlet and on the North Slope

Table 5 summarizes the results of computer modeling of in situ crude oil burns involving meteorological conditions typical of Cook Inlet and of the North Slope in flat terrain. The table lists the greatest downwind distances at which concentrations of $PM_{2.5}$ are expected to reach 65 micrograms per cubic meter at ground level. On-scene coordinators may use the predictions in Table 5 as safe distances for burns over flat terrain in Cook Inlet and on the North Slope instead of the green zone distances in Table 4.

New $PM_{2.5}$ National Ambient Air Quality Standard

The $PM_{2.5}$ safe distance criterion in these guidelines reflects the new National Ambient Air Quality Standards' 65 microgram per cubic meter threshold. The 1-hour period follows the recommendations of the National Response Team Science & Technology Committee (1995) and reflects the lack of a formal short-term exposure limit for particulate matter.

The national primary and secondary ambient air quality standards for particulate matter now include the standard of 65 micrograms per cubic meter 24-hour average concentration measured in the ambient air as $PM_{2.5}$. The $PM_{2.5}$ 24-hour standard is met when the 3-year average of the annual 98th percentile concentration values of measurements over 24-hour periods at monitoring sites is less than or equal to 65 micrograms per cubic meter.

The U.S. Environmental Protection Agency (1997) revised the National Ambient Air Quality Standards regulations for particulate matter in a final rule effective September 16, 1997. The preamble stated that the 65 microgram concentration level provides some margin of safety, yet recognizes that the risk associated with infrequent peak 24-hour exposures in otherwise clean areas is not well understood.

In the same ruling, the U.S. Environmental Protection Agency made two other changes to the particulate matter standards. The agency added an annual $PM_{2.5}$ standard of 15 micrograms per cubic meter, based on the 3-year average of annual arithmetic means. The agency also retained the PM_{10} 150 micrograms per cubic meter 24-hour standard, but revised its method of calculation. The 24-hour PM_{10} standard is met when the 3-year average of the annual 99th percentile values at each monitoring site is less than or equal to 150 micrograms per cubic meter. The method replaces the former criterion of no more than one exceedance per year.

Table 5
ALOFT Predictions of Downwind Safe Distances for Ground-Level $PM_{2.5}$ Concentrations of 65 Micrograms per Cubic Meter over Flat Terrain.
Simulations are based on atmospheric conditions typical of Cook Inlet and the North Slope.

Burning Area	Season	Regional Source of Meteorological Data	Wind Speed (knots)	Downwind Distance (miles)	
				Land	Water
2,500 square feet	Summer	Cook Inlet	8	<0.6	<0.6
			16	1.5	<0.6
			23	1.8	<0.6
		North Slope	8, 16, 23	<0.6	<0.6
	Winter	Cook Inlet and North Slope	8, 16	<0.6	<0.6
			23	0.9	<0.6
5,000 square feet	Summer	Cook Inlet	8	<0.6	<0.6
			16	1.2	<0.6
			23	2.4	<0.6
		North Slope	8, 16, 23	<0.6	<0.6
	Winter	Cook Inlet and North Slope			
10,000 square feet	Summer and Winter	Cook Inlet and North Slope	16	<0.6	<0.6

Adapted from Bronson, 1998.

Consideration of Moving Source

The on-scene coordinators may consider that a moving in situ burn may expose people to less smoke than a stationary fire. Even in a yellow zone, the public may not become exposed to smoke for very long if the smoke plume is translating over a population.

For example, the smoke from a continuous in situ burn in Cook Inlet may blow over the city of Kenai, borne by a wind from the west. Concurrently, the tidal current carries the fire and its smoke plume southward at several knots. The width of the plume passes over a residential area in a matter of 15 or 20 minutes. Thus, at a point in Kenai where the smoke's $PM_{2.5}$ concentration equals 65 micrograms per cubic meter, the plume's short duration there brings the 1-hour average exposure well below 65 micrograms per cubic meter.

Conditions of Authorization

Authorization to conduct an in situ burn includes conditions of authorization. The burn operations team must visually monitor the smoke plume and consider all possible methods to collect the burn residue. The on-scene coordinators may impose other conditions to protect human health.

The on-scene coordinators notify the public in green, yellow, and red zones that burning is occurring (Level 1) and the area is to be avoided. Avenues for notifying the public include radio/TV broadcasts, road closures, marine safety zones, broadcasts to mariners and other appropriate means. See Table 7 for a list of notification levels.

In the yellow zone, where the ALOFT model predicts airborne $PM_{2.5}$ concentration is anticipated to exceed 65 micrograms per cubic meter 1-hour average in an area with human presence, the on-scene coordinators may also implement higher levels of public notification. Level 2, alert notification, is public notification/warning involving a medical alert to persons with existing conditions that put them at risk to air quality degradation.

Level 3, warning notification, is public notification/warning in the yellow zone with in-place sheltering instructions for a specified period of time. The on-scene coordinators implement Level 3 notification upon their discretion, or when modeled air emission patterns indicate a particulate matter level greater than state air quality alert/warning levels.

The on-scene coordinators implement emergency notification to temporarily evacuate the yellow or red zone at their discretion. This Level 4 is the most stringent and extreme measure of public notification/warning and is only anticipated to be used to relocate a small number of people for a short period of time. The authority to order such an evacuation is vested in local government or, if no local government exists, state officials.

In situ burns authorized in accordance with these guidelines, using a safe distance, should not ordinarily require Level 2, 3, or 4 notifications. The notifications are a contingency if the plume does not dissipate as modeled. The notifications may also be used for sheltering in-place or evacuating small numbers of people for a short period of time (e.g., fishermen, hunters, backpackers, recreational boaters, rural residents, offshore platform operators, pump station or highway camp personnel).

4. PUBLIC HEALTH AND THE ENVIRONMENT

Public Health

Smoke from in situ burns contains chemicals and particulates that may be toxic, much like emissions from motor vehicles, power plants, wood stoves, and slash burning. For example, the sulfur dioxide emissions from the Newfoundland Offshore Burn Experiment were equivalent to sulfur dioxide emissions from an average coal-fired power plant. The carbon monoxide emissions were equivalent to emissions from a 0.2-acre forest slash burn or 2,400 wood stoves, and the soot particle emissions were equivalent to a 9-acre slash burn or 58,000 wood stoves (S.L. Ross 1997).

Table 6 lists the air quality thresholds for many smoke plume components. Table 7 describes the health effects associated with the pollutants.

Table 6
Air Quality Standards

	Averaging Periods				
Contaminant (units)	Annual	24-hour	8-hour	3-hour	1-hour
National Ambient Air Quality Standards					
$PM_{2.5}$ ($\mu g/m^3$)	15	65	—	—	—
PM_{10} ($\mu g/m^3$)	50	150	—	—	—
CO (ppm)	—	—	9	—	35
SO_2 (ppm)	0.03	0.14	—	—	—
NO_2 (ppm)	0.053	—	—	—	—
Alaska State Regulatory Standards					
$PM_{2.5}$ ($\mu g/m^3$)	15	65	—	—	—
PM_{10} ($\mu g/m^3$)	50	150	—	—	—
CO (mg/m^3)	—	—	10	—	40
Sulfur oxides ($\mu g/m^3$)	80	365	—	1,300	—
NO_2 ($\mu g/m^3$)	100	—	—	—	—
OSHA Permissible Exposure Limits					
Total particulates (mg/m^3)	—	—	15	—	—
Respirable particulates (mg/m^3)	—	—	5	—	—
CO (ppm)	—	—	50	—	—
SO_2 (ppm)	—	—	5	—	—
NO_2 (ppm)	—	—	5	—	—
CO_2 (ppm)	—	—	10,000	—	—
PAH (mg/m^3)	—	—	0.2	—	—
Benzene (in VOC) (ppm)	—	—	1	—	—

Adapted from Table 2, McGrattan et al., 1997, and Annex D, NRT, 1997b.

Table 7
Pollution Standard Index Values and Associated Health Effects.
$PM_{2.5}$ pollutant levels are pending with EPA.

Index Value	Air Quality Level (Public Notification Level)	Pollutant Levels: PM_{10} (24-hour) $\mu g/m^3$	SO_2 (24-hour) $\mu g/m^3$	CO (8-hour) ppm	O_3 (1-hour) ppm	NO_2 (1-hour) ppm	Health Effect Descriptor	General Health Effects	Cautionary Statements
500	Significant Harm	600	2620	50	0.6	2.0		Premature death of ill and elderly. Healthy people will experience adverse symptoms that affect their normal activity.	All persons should remain indoors, keeping windows and doors closed. All persons should minimize physical exertion.
400	Emergency (Level 4)	500	2100	40	0.5	1.6	Hazardous	Premature onset of certain diseases in addition to significant aggravation of symptoms and decreased exercise tolerance in healthy persons.	Elderly and persons with existing diseases should stay indoors and avoid physical exertion. General population should avoid outdoor activity.
300	Warning (Level 3)	420	1600	30	0.4	1.2	Very Unhealthful		
200	Alert (Level 2)	350	800	15	0.2	0.6		Significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease, with widespread symptoms in the healthy population.	Elderly persons with existing heart or lung diseases should reduce physical activity.
100	NAAQS (Level 1)	150	365	9	0.12	a	Unhealthful		
50	50 % of NAAQS	50	80[b]	4.5	0.06	a	Moderate	Mild aggravation of symptoms in susceptible persons, with irritation symptoms in the healthy population.	Persons with existing heart or respiratory ailments should reduce physical exertion and outdoor activity.
0		0	0	0	0	a	Good		

[a]No index values reported at concentration levels below those specified by “Alert Level” criteria. [b]Annual primary NAAQS.
Source: Centers for Disease Control

Particulates. Oil burns produce soot equal to 10 to 20 percent of the mass of the burned oil (Fraser, Buist, and Mullin 1997). In most large-scale burns, not enough air is drawn into the fire for complete combustion. The burn continues under “starved combustion,” and produces a thick, dense, black plume of smoke composed of partially-burned byproducts in particulate (soot) and gaseous form.

Particulates are small pieces of solid materials (e.g., dust, soot) or liquid material (e.g., mist, fog, spray) that remain suspended in the air long enough to be inhaled. Particulate size plays a crucial role in health effects, because it affects how far the particles travel before they settle out of the air and how deeply they are inhaled into the lungs. Particulates larger than 10 microns in diameter settle 1 foot in less than a minute in still air, so they tend to settle in the environment quickly and generally are not inhaled. Particulates 0.5 micron in diameter, however, take 5-1/2 hours to settle 1 foot. Therefore, the smaller particulates travel farther from the burn site before they settle out of the air (Shigenaka and Barnea 1993).

Particulates 5 to 10 microns in diameter may be inhaled, but most are deposited in the upper respiratory tract and cleared by mucociliary action, which is efficient and relatively rapid. Only particulates smaller than 5 microns in diameter reach the sensitive alveolar portion of the lungs. Clearance of particulates reaching this part of the lungs is much slower and less efficient. The median size of particulates reaching the alveolar portion of the lungs is 0.5 micron. The mean size of particulates produced by an in situ burn is also 0.5 micron.

For most people, exposure to particulates only becomes a concern at high concentrations. Inhaling high doses of particulates can overwhelm the respiratory tract and cause breathing difficulties (Shigenaka and Barnea 1993). However, for the very old and very young, and for people with allergies, respiratory problems, and cardiovascular disease, exposure to particulates can become a concern at much lower concentrations.

Several experiments found high particulate concentrations at ground level only close to the fire. During the Newfoundland Offshore Burn Experiment, particulates were a concern only up to 150 meters downwind of the fire at sea level; particulate levels dropped to background levels at 1 kilometer downwind of the fire (Fingas et al. 1994a). Particulates in the smoke plume were 800 to 1,000 micrograms per cubic meter near the fire. However, the PM_{10} concentrations beneath the plume, even at heights up to 150 to 200 feet above the sea surface and 1 kilometer downwind, never exceeded background levels (30 to 40 micrograms per cubic meter). Ground-level concentrations beneath a plume from an Alaska North Slope crude oil test burn on the North Slope declined from 86 micrograms per cubic meter 0.5 mile downwind to 22 micrograms per cubic meter 2 miles downwind. Measurements of near-ground smoke concentrations under the plume from two diesel fires in Mobile, Alabama, peaked at 25 micrograms per cubic meter 6 miles downwind in one case and 15 micrograms per cubic meter 6 miles downwind in the other (S.L. Ross 1997).

Polynuclear Aromatic Hydrocarbons. Polynuclear aromatic hydrocarbons (PAHs) are found in oil and oil smoke. Some PAHs are known or suspected toxins or carcinogens. Long-term exposure to the higher molecular weight PAHs is generally the basis for human health concerns.

The PAHs in oil are largely consumed by combustion. During the Newfoundland Offshore Burn Experiment, PAH concentrations were much less in the plume and in particulate precipitation at ground level than they were in the starting oil. The mass of all PAHs, including the larger or multiringed PAHs, was reduced by about 6 orders-of-magnitude using combustion (Fingas et al. 1994b).

Westphal et al. (1994) estimated an excess cancer risk of 5 in 100,000 from breathing or ingesting PAHs in soil after a hypothetical burn of 10,000 gallons of crude oil. This risk is within U.S. Environmental Protection Agency guidelines for acceptable risk levels. The researchers found no concern for noncarcinogenic effects from the PAHs. They concluded that adverse health effects from exposure to PAHs "may not be a significant factor in making a burn/no burn situation." Similarly, ASTM (1997), in assessing the results of several experimental burns, concluded: "In all cases, the quantity of PAHs is less in the soot and residue than in the originating oil . . . PAHs are not a serious concern in assessing the impact of burning oil."

Gases. Unlike particulate matter, the gases emitted during a burn do not pose a threat to human health, because the concentrations in the smoke plume fall below levels of concern at very short distances downwind of a burn (S.L. Ross 1997 and Bronson 1998).

Volatile organic compounds such as benzene, toluene, n-hexane, and naphthalene can contribute to acute health effects, such as nausea and headache, at high concentrations. High concentrations of volatile organic compounds were present within about 150 to 200 meters of experimental fires (Fingas et al. 1994a). However, even higher levels of volatile organic compounds are emitted from an evaporating slick that is not burning. Therefore, burning actually results in lower air concentrations of volatile organic compounds than other remedial actions (Westphal et al. 1994).

Carbon monoxide is a common by-product of incomplete combustion. It is acutely toxic because it displaces oxygen from the blood and causes oxygen deprivation in the body's cells. Carbon monoxide was not detected in the smoke plume from the Newfoundland Offshore Burn Experiment (Fingas et al. 1994b). During the Kuwait oil pool fires, carbon monoxide levels were much below levels considered to be dangerous (Ferek et al. 1992). Measurements from other experiments show that at ground level 30 meters downwind of an in situ burn, concentrations are at or near background levels or are below detection levels (S.L. Ross 1997).

Sulfur dioxide is toxic and may severely irritate the eyes and respiratory tract. Sulfur dioxide was not detected in the smoke plume from the Newfoundland Offshore Burn Experiment (Fingas et al. 1994b). Measurements from mesoscale burns ranged from below detection limits to peaks of 1.2 ppm 100 feet downwind, well below the regulatory standards (see Table 6) (S.L. Ross 1997).

Nitrogen oxides are strong irritants to the eyes and respiratory tract. The maximum concentration of nitrogen dioxide found in the plume from the Kuwait oil fires was 0.02 ppm (Ferek et al. 1992), well below the annual National Ambient Air Quality Standard of 0.053 ppm. Levels of nitrogen oxides in mesoscale burns were below levels of detectability and thus below levels of concern (S.L. Ross 1997).

Ecological Concerns

The Alaska Regional Response Team aims to protect wildlife and habitat threatened by an oil spill by using in situ burning under certain conditions. The U.S. Department of Interior, U.S. Department of Commerce, and Alaska Department of Fish and Game helped write Revision 0 of the *In Situ Burning Guidelines for Alaska* with other members of the Alaska Regional Response

Team's Science and Technology Committee. The Committee advocated in situ burning where mechanical methods become inadequate to contain and remove spilled oil. The Committee decided that in situ burning can reduce the threat to wildlife posed by untreated oil, and that this benefit outweighs the potential harm posed by in situ burning smoke and residue. The Committee also decided not to require the incident-specific identification of wildlife threatened by in situ burning.

Campbell et al. (1994) studied the environmental trade-offs of in situ burning. They concluded that in offshore, nearshore, and estuarine environments, burning a crude oil spill poses less risk to wildlife than not burning. Burning greatly reduces the volume of oil and therefore the probability that oil comes in contact with wildlife. Burning also eliminates the volatile/soluble fraction of the spill.

Surface Microlayer. The surface of the water represents a unique and important ecological niche called the surface microlayer, usually considered to be the upper millimeter or less of the water surface. This layer is a habitat for many sensitive life stages of marine organisms, including eggs and larval stages of fish and crustaceans, and reproductive stages of other plants and animals. The egg or larval stages of cod, sole, flounder, hake, anchovy, crab, and lobster develop in this layer. The surface microlayer frequently contains dense populations of microalgae, with species compositions distinct from the phytoplankton below the microlayer (Shigenaka and Barnea 1993).

Potential impacts to the ecologically important surface microlayer are tempered by the ephemeral nature of the burn and its associated residual material. The Office of Technology Assessment (1986) noted in an evaluation of ocean incineration, "given the intermittent nature of ocean incineration, the relatively small size of the affected area, and the high renewal rate of the surface microlayer resulting from new growth and replenishment from adjacent areas, the long-term net loss of biomass would probably be small or non-existent."

Aquatic toxicity and concentrations of petroleum hydrocarbons in the water in the vicinity of both burned and unburned crude oil slicks in the open sea is very low. No significant differences were found in the measurements of toxicity or petroleum hydrocarbons among water samples associated with unburned oil, burning oil, or post-burn scenarios (Daykin et al. 1994). Burning does not accelerate the release of oil components or combustion by-products to the water column (ASTM 1997).

In large-scale burns, temperature increases in the water do not appear to be a problem. During the Newfoundland Offshore Burn Experiment, the water under the burn showed no increase in temperature, even though the temperatures at the top of the fire containment boom often reached 1000°C (Fingas et al. 1994a). The water probably does not heat up because ambient-temperature seawater is continually supplied below the oil layer as the boom is towed (Shigenaka and Barnea 1993).

Burn Residue. Both residue that floats and residue that sinks may pose some risk of toxicity or contamination to organisms in the water column (S.L. Ross 1997). Residue that floats may pose a threat to shorelines and wildlife. The residue may be ingested by fish, birds, and mammals. The residue also may foul gills, feathers, fur, or baleen (Shigenaka and Barnea 1993). Residue that sinks may affect benthic animals. In general, however, the effects are less severe than those from a large, uncontained oil spill, and no specific biological concerns have been identified to date (ASTM 1997). Oil samples and burn residues collected after the Newfoundland Offshore Burn

Experiment were tested for toxicity to three aquatic species. Neither the residue nor the oil was toxic, and the burn residue was no more toxic than the oil itself (Blenkinsopp et al. 1997).

Residues of Alaska North Slope crude oil are likely to be sticky semi-solids or non-sticky solids, depending on the weathering of the oil and the efficiency of the burn. Sticky residues pose a greater potential environmental risk. They may adhere to birds' feathers and disrupt the waterproofing of their plumage or be ingested while the bird is preening (S.L. Ross 1997).

Sunken burn residues can affect benthic resources that would not otherwise be significantly impacted by a spill at the surface of the water. For example, during the *Haven* spill in Italy in 1991, approximately 102,000 metric tons of oil burned, and the residues sank. The residue was distributed over approximately 140 square kilometers of seabed. Local trawl fishermen were unwilling to fish in the area for two years after the spill because of the expected danger of contaminating their nets and catch (Martinelli et al. 1995). In 1983, cleanup contractors ignited the main slick of a spill of Arabian heavy crude from the *Honam Jade* in South Korea. The fire burned intensely for about two hours, and the resultant burn residue sank and impacted crabs in nearby pens (Moller 1992).

5. REVISIONS AND ACKNOWLEDGMENTS

In March 1989, the Alaska Regional Response Team adopted the "Oil Spill Response Checklist: In Situ Burning" for use by a party responding to a spill. The checklist was subsequently revised and approved by the Alaska Regional Response Team on July 15, 1992. On February 4, 1991, the Alaska Regional Response Team approved the "Alaska Regional Response Team In Situ Burning Memorandum of Agreement: Beaufort and Chukchi Seas and Selected North Slope Areas." In 1994, the Alaska Regional Response Team incorporated the *In Situ Burning Guidelines for Alaska* into its Unified Plan; the *In Situ Burning Guidelines for Alaska* superseded both the checklist and the memorandum of agreement. This version (Revision 1) updates the 1994 guidelines, but is not a pre-approval under the National Contingency Plan. Consultation, as required by the NCP, is necessary.

The guidelines were drafted by the Science and Technology Committee of the Alaska Regional Response Team. Member agencies include the United States Environmental Protection Agency, Alaska Department of Environmental Conservation, United States Coast Guard, United States Department of the Interior, United States Department of Commerce, Alaska Department of Fish and Game, National Oceanic and Atmospheric Administration, and advisory representatives from the oil industry, Native communities, fishing industry, and the Regional Citizens Advisory Councils. From time to time, other entities including Cook Inlet Spill Prevention and Response Incorporated, Alaska Clean Seas, Alyeska Pipeline Service Company, Alaska Fishermen United, the Pacific Rim Native Corporation, and others have contributed significantly.

6. REFERENCES

Alaska Regional Response Team. 1994. In Situ Burning Guidelines for Alaska. Appendix II, Annex F, in The Alaska Federal/State Preparedness Plan for Response to Oil and Hazardous Substance Discharges/Releases.

Allen, A. and R. Ferek. 1993. Advantages and disadvantages of burning spilled oil. In Proceedings of the 1993 International Oil Spill Conference. March 29-April 1. Tampa, Florida. pp. 765-772.

Allen, A. 1990. Contained controlled burning of spilled oil during the *Exxon Valdez* oil spill. In Proceedings of the Thirteenth Arctic and Marine Oilspill Program (AMOP) Technical Seminar. June 6-8, Edmonton, Alberta, pp. 305-313.

Alyeska Pipeline Service Company. 1996. Supplemental Information Document #16: Burning as a Response Tool. In Prince William Sound Tanker Oil Discharge Prevention and Contingency Plan, Supplemental Information Documents, Edition 1, Revision 1, dated December 31, 1996, Alyeska documents no. PWS-203-16. Anchorage. 92 pp.

American Society for Testing and Materials (ASTM). 1997. Standard guide for in situ burning of oil spills on water: Environmental and operational considerations. Designation: F 1788-97. July.

Blenkinsopp, S., G. Sergy, K. Li, M. Fingas, K. Doe, and G. Wohlgeschaffen. 1997. Evaluation of the toxicity of the weathered crude oil used at the Newfoundland Offshore Burn Experiment (NOBE) and the resultant burn residue. In Proceedings of the Twentieth Arctic and Marine Oilspill Program (AMOP) Technical Seminar. June 11-13. Vancouver, British Columbia. pp. 677-684.

Bronson, M. 1998. In situ burning safe distance predictions with ALOFT-FT model. Prepared by EMCON Alaska, Inc., for Alaska Department of Environmental Conservation.

Buist, I., J. McCourt, and J. Morrison. 1997. Enhancing the in situ burning of five Alaskan oils and emulsions. 1997. In Proceedings of the 1997 International Oil Spill Conference. April 7-10. Fort Lauderdale, Florida. pp. 121-129.

Buist, I., J. McCourt, K. Karunakaran, C. Gierer, D. Comins, N. Glover, and B. McKenzie. 1996. In situ burning of Alaskan oils and emulsions: Preliminary results of laboratory tests with and without waves. In Proceedings of the Nineteenth Arctic and Marine Oilspill Program (AMOP) Technical Seminar, June 12-14, Calgary, Alberta, pp. 1033-1061.

Buist, I., K. Trudel, J. Morrison, and D. Aurand. 1995a. Laboratory studies of the physical properties of in situ burn residues. In Proceedings of the Eighteenth Arctic and Marine Oilspill Program (AMOP) Technical Seminar, June 14-16, Edmonton, Alberta, pp. 1027-1051.

Buist, I., N. Glover, B. McKenzie, and R. Ranger. 1995b. In situ burning of Alaska North Slope emulsions. In Proceedings of the 1995 International Oil Spill Conference. February 27-March 2. Long Beach, California. pp. 139-146.

Buist, I. 1989. Disposal of spilled Hibernia crude oils and emulsions: In situ burning and the "Swirlfire" burner. In Proceedings of the Twelfth Arctic and Marine Oilspill Program (AMOP) Technical Seminar. June 7-9, Calgary, Alberta, pp. 245-277.

Buist, I., and D. Dickins. 1987. Experimental spills of crude oil in pack ice. In Proceedings of the 1987 International Oil Spill Conference, pp. 373-380.

Campbell, T., E. Taylor, and D. Aurand. 1994. Ecological risks associated with burning as a spill countermeasure in a marine environment. In Proceedings of the Seventeenth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, June 8-10, Vancouver, British Columbia, pp. 707-716.

Daykin, M., G. Sergy, D. Aurand, G. Shigenaka, Z. Wang, and A. Tang. 1994. Aquatic toxicity resulting from in situ burning of oil-on-water. In Proceedings of the Seventeenth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar. June 8-10. Vancouver, British Columbia. pp. 1165-1193.

Ferek, R., P. Hobbs, J. Herring, K. Laursen, R. Weiss, and R. Rasmussen. 1992. Chemical composition of emissions from the Kuwait oil fires. Journal of Geophysical Research 97: 14483-14489.

Fingas, M., F. Ackerman, K. Li, P. Lambert, Z. Wang, M. Bissonnette, P. Campagna, P. Boileau, N. Laroche, P. Jokuty, R. Nelson, R. Turpin, M. Trespalacios, G. Halley, J. Belanger, J. Pare, N. Vanderkooy, E. Tennyson, D. Aurand, and R. Hiltabrand. 1994a. The Newfoundland Offshore Burn Experiment: NOBE preliminary results of emissions measurement. In Proceedings of the Seventeenth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar. June 8-10. Vancouver, British Columbia. pp. 1099-1164.

Fingas, M., G. Halley, F. Ackerman, N. Vanderkooy, R. Nelson, M. Bissonnette, N. Laroche, P. Lambert, P. Jokuty, K. Li, W. Halley, G. Warbanski, P. Campagna, R. Turpin, M. Trespalacios, D. Dickins, E. Tennyson, D. Aurand, and R. Hiltabrand. 1994b. The Newfoundland Offshore Burn Experiment: NOBE experimental design and overview. In Proceedings of the Seventeenth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar. June 8-10. Vancouver, British Columbia. pp. 1053-1063.

Fraser, J., I. Buist, and J. Mullin. 1997. A review of the literature on soot production during in situ burning of oil. In Proceedings of the Twentieth Arctic and Marine Oilspill Program (AMOP) Technical Seminar. June 11-13. Vancouver, British Columbia. pp. 1365-1405.

Guenette, C., and P. Sveum. 1995. In situ burning of uncontained crude oil and emulsions. In Proceedings of the Eighteenth Arctic and Marine Oilspill Program (AMOP) Technical Seminar, June 14-16, Edmonton, Alberta, pp. 997-1010.

Hossain, K., and D. MacKay. 1981. A study of the combustibility of weathered crude oils and water-in-oil emulsions. Report EE-12 prepared for Environment Canada, Environmental Emergency Branch, Research and Development Division, 15 pages plus appendices.

Industry Task Group. 1984. Oil Spill Response in the Arctic, Part 3, Technical Documentation. Shell Western E&P, Inc.; Sohio Alaska Petroleum Company; Exxon Company, U.S.A.; and Amoco Production Company. Anchorage, Alaska. 76 pp.

Martinelli, M., A. Luise, E. Tromellini, T. Sauer, J. Neff, G. Douglas. 1995. The M/C *Haven* oil spill: Environmental assessment of exposure pathways and resource injury. In Proceedings of the 1995 International Oil Spill Conference. February 27-March 2, Long Beach, California, pp. 679-685.

McGrattan, K., H. Baum, W. Walton, and J. Trelles. 1997. Smoke plume trajectory from in situ burning of crude oil in Alaska: Field experiments and modeling of complex terrain. U.S. Department of Commerce, National Institute of Standards and Technology. January. 127 pages.

Moller, T.H. 1992. Recent experience of oil sinking. In Proceedings of the Fifteenth Arctic and Marine Oilspill Program (AMOP) Technical Seminar. June 10-12, Edmonton, Alberta, pp. 11-14.

National Oceanic and Atmospheric Administration (NOAA), Hazardous Materials Response and Assessment Division. 1994. ADIOS (Automated Data Inquiry for Oil Spills) User's Manual. Prepared for The U.S. Coast Guard Research and Development Center, Avery Point, Groton, Connecticut. April.

National Response Team Science & Technology Committee. 1997a. Guidance for developing a site safety plan for marine in situ burn operations. November.

National Response Team Science & Technology Committee. 1997b. Fact sheet: Site safety plans for marine in situ burning operations. November.

National Response Team Science & Technology Committee. 1995. Guidance on burning spilled oil in situ. December.

Office of Technology Assessment. 1986. Ocean Incineration: Its Role in Managing Hazardous Waste. Washington, DC: U.S. Government Printing Office, 223 pages.

Shigenaka, G., and N. Barnea. 1993. Questions about in situ burning as an open-water oil spill response technique. National Oceanic and Atmospheric Administration. HAZMAT Report 93-3. June. 42 pages.

S.L. Ross Environmental Research Ltd. 1997. A review of in situ burning as a response for spills of Alaska North Slope crude oil in Prince William Sound. Prepared for Prince William Sound Regional Citizens Advisory Council. May 20.

Trudel, B.K., I.A. Buist, D. Schatzke, and D. Aurand. 1996. Laboratory studies of the properties of in situ burn residues: Chemical composition of residues. In Proceedings of the Nineteenth Arctic and Marine Oilspill Program (AMOP) Technical Seminar, June 12-14, Calgary, Alberta, pp. 1063-1079.

U.S. Environmental Protection Agency. 1997. National Ambient Air Quality Standards for Particulate Matter; Final Rule, 40 CFR Part 50. Federal Register 62 FR 138, July 18, 1997, prepublication. 102 pages.

U.S. Environmental Protection Agency. 1991. In situ burning workshop, May 21-22, 1991, Sacramento, California. 7 pp. + appendices.

Westphal, P., E. Taylor, and D. Aurand. 1994. Human health risk associated with burning as a spill countermeasure. In Proceedings of the Seventeenth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, June 8-10, Vancouver, British Columbia, pp. 685-705.

APPLICATION AND BURN PLAN
In Situ Burning Guidelines for Alaska

<table>
<tr><td rowspan="4">Incident Name: ____________________

Incident Location: ____________________

Incident Date: ____________________

Incident Time: ____________________</td><td colspan="2" rowspan="2"><u>Date Prepared</u></td><td colspan="2">Operational Period</td></tr>
<tr><td>Date</td><td>Time</td></tr>
<tr><td rowspan="2">Time
<u>Prepared</u></td><td>Start:</td><td></td><td></td></tr>
<tr><td>End:</td><td></td><td></td></tr>
</table>

Title of Applicant: ____________________ Address: ____________________

Affiliation: ____________________ Phone: ____________ Fax: ____________

STEP 1

Site Location ____________________
Site Description ____________________
Latitude ____________________
Longitude____________________

Type of Incident (check one):
_______Grounding
_______Transfer Operations
_______Explosion
_______Collision
_______Blowout
_______Other ____________________

Product Released (check one):
_______North Slope Crude
_______Cook Inlet Crude
_______Chevron Residual
_______Diesel #2
_______JP4
_______Other ____________________

Estimated Volume of Released Product:
____________________ gallons, or
____________________ BBL

Estimated Volume of Product That May Potentially be Released:
____________________ gallons, or
____________________ BBL

Release Status (check one):
______Continuous
______Intermittent
______One time only, now stopped

If Continuous or Intermittent, Rate of Release:
____________________gallons, or
____________________BBL

Estimated Water Surface Covered (square miles)
____

Why is mechanical recovery alone inadequate to control the spill? Consider the spill size, forecasted weather and trajectories, amount of available equipment, time to deploy, and time to recover.____________________
____
____

Will you use mechanical recovery in conjunction with in situ burning? yes no

Have you evaluated dispersants? yes no

Will you use dispersants in conjunction with in situ burning? yes no

Why is in situ burning preferred? ____________________
____
____

APPLICATION AND BURN PLAN
In Situ Burning Guidelines for Alaska

STEP 2

Did source burn? yes no

Is source still burning? yes no

Is product easily emulsified? yes no

Is product already emulsified? (check one)

_______No

_______Light emulsion (0-20%)

_______Moderate emulsion (21-50%)

_______Heavy emulsion (>50%)

_______Unknown

Estimated Percent Oil Naturally Dispersed and Evaporated Within First 24 Hours: ______________________

Check boxes and enter wind values in the following table:

	Current Conditions	12-hour Forecast	24-hour Forecast
Clear			
Partly cloudy			
Overcast			
Rain			
Snow			
Fog			
Wind Speed (kt)			
Wind Direction (from)			

Percentage Ice Coverage (check one):

_______No ice present

_______<10%

_______11-30%

_______31-50%

_______51-100%

Tidal state at ____________ o'clock (check one):

______Slack tide

______Incoming (flood)

______Outgoing (ebb)

Attach a graph with tidal information for three tidal cycles.

Dominant current (not drift):

Speed (knots) _________________________

Direction (to) __________________________

Current Speed (knots) Relative to the Containment Boom ___________________________________

Sea State (check one):

______Calm

______Choppy

______Swell

Waves (estimate height in feet)____________

Does your site safety plan cover this in situ burn plan? yes no

Will response workers be briefed on the site safety plan before burning? yes no

Are the responders trained and equipped with safety gear? yes no

Attach an ICS 204 form, or similar document. On it, list the following equipment you will use:

- Vessels
- Aircraft for ignition and aerial observation
- Lengths of fire boom
- Residue containment equipment
- Fire fighting equipment
- Ignition systems
- Burn promoters
- Communications systems

Proposed Burn Date and Time ______________

APPLICATION AND BURN PLAN
In Situ Burning Guidelines for Alaska

Describe how you intend to carry out the burn.

____

Check one:

_______Ignition is away from source after containment and movement of the oil to safe location (i.e., controlled burn).

_______Ignition of uncontained slick(s) is at a safe distance from the source.

_______Ignition is at or near source without controls.

How will you ignite the oil?____________________________

____

Enter the volume of oil you expect to burn:

Fire No.	Oil Volume (BBL__ or Gal__)	Fire Duration (Hrs__ or Min__)
1		
2		
3		
4		
5		
Attach a list for more fires.		
Total Vol.:		

How many simultaneous burns are planned?

____

What distance will separate simultaneous burns?

____

Are you planning sequential or repeat (not simultaneous) burns? yes no

Estimated area of oil in uncontrolled burn
(square feet) _____________________________________

Describe your ability and procedures to extinguish the burn if necessary or directed to do so.

____

____

Step 3

Attach a chart with a distance scale. Show estimated spill trajectory and landfalls, with time. Show the location and distance of your proposed burns relative to the following features:

1. Source:

Location____

Distance from Burn (miles) ________________________

2. Ignitable slicks:

Location____

Distance from Burn (miles) ________________________

3. Nearest Land (burns on water) or Non-Flat Terrain (burns on land):

Location____

Distance from burn (miles) ________________________

4. Nearby Human Populations and Human Use Areas (names of towns, etc.):

Location____

Distance from Burn (miles) ________________________

Location____

Distance from Burn (miles) ________________________

Location____

Distance from Burn (miles) ________________________

5. Show your mechanical recovery and in situ burning equipment configurations.

Step 4

How do you plan to collect burned oil residue?

____

____

How do you plan to store and dispose of burned oil residue?

____

____

APPLICATION AND BURN PLAN
In Situ Burning Guidelines for Alaska

Describe the risk of accidental (secondary) fire.

____

How much will your burn impair visibility at airports?

____

How far is your proposed burn from the nearest Class I airshed?[1] ______________________________________

[1] Class I airsheds in Alaska:
- Denali National Park and Preserve
- Bering Sea National Wildlife Refuge National Wilderness Area
- Simeonof National Wildlife Refuge National Wilderness Area
- Tuxedni National Wildlife Refuge National Wilderness Area (this area lies adjacent to Cook Inlet)

Special protection of visibility is also designated in the following areas
- Mt. Deborah and the Alaska Range East viewed from the Savage River Campground area
- Mt. McKinley, Alaska Range, and Interior Lowlands viewed from Wonder Lake

Signatures

____
Signature of Applicant

____
Printed name of Applicant

____
Date and Time Submitted to Federal and State On-Scene Coordinators

Prepared By: ____________________ ICS Position: ____________________ Phone: __________

ON-SCENE COORDINATORS' REVIEW CHECKLIST
In Situ Burning Guidelines for Alaska

STEP 1

Is mechanical containment and recovery alone insufficient or unfeasible?	yes	no

STEP 2

Will the oil become 2 to 3 mm thick?	yes	no
Is the oil fresh (less than 2 or 3 days of exposure)?	yes	no
Is the oil emulsified by less than 25 percent?	yes	no
Is visibility sufficient to see oil and vessels towing boom, and suitable for aerial overflight for burn observation?	yes	no
Is wind less than 20 knots?	yes	no
Are currents less than 0.75 knots relative to the boom?	yes	no
Are waves less than 3 feet in choppy, wind-driven seas or less than 5.7 feet in large swells?	yes	no
Does the responsible party have a site safety plan for this incident that specifically addresses the proposed burning operations?	yes	no
Will response workers be briefed on this plan before burning starts?	yes	no
Are personnel trained and equipped with safety gear?	yes	no
Is a communications system available and working to communicate with aircraft, vessels, and control base?	yes	no
Are operational and environmental conditions feasible for burning?	yes	no
For burns not in broken ice, can the responder extinguish the fire?	yes	no
Will the burn meet the operational criteria for:		
the next 24 hours?	yes	no
the next 48 hours?	yes	no

STEP 3

Burning Near Unpopulated Areas:

Will the smoke pass into populated areas?	yes	no

If no, proceed to Step 4. If yes, consider the following conditions of authorization.

ON-SCENE COORDINATORS' REVIEW CHECKLIST
In Situ Burning Guidelines for Alaska

Burning in Flat Terrain Near Populated Areas:

On water more than 3 miles from shore, the Green Zone safe distance is 1 mile from non-responders. On land or on water less than 3 miles from shore, the green zone safe distance is 3 miles from human populations. Burning at a green zone safe distance from people is acceptable. Proceed to Step 4.

The Yellow Zone distance is from 1 to 3 miles downwind of a burn, and within 45 degrees of the smoke plume, when the burn is on land or on water within 3 miles of shore. If the impacted population can be sheltered in place or evacuated during the burn, proceed to Step 4. If people cannot be protected, do not authorize burning at this time.

The Red Zone distance is within 1 mile of any burn. Burns within 1 mile of people may be authorized if the impacted population can be sheltered in place or evacuated during the burn, and if best professional judgment supports the expectation of PM2.5 less than 65 micrograms per cubic meter 1-hour average in populated areas. If these conditions can be met, proceed to Step 4. If these conditions cannot be met, do not authorize burning at this time.

Burning when the Safe Distance Is Not Predicted:

According to best professional judgment, will $PM_{2.5}$ concentrations remain below 65 micrograms per cubic meter 1-hour average in populated areas? yes no

If yes, proceed to Step 4. If no, do not authorize burning at this time.

STEP 4

Notifications and Warnings:

Is the burn in an area near or adjacent to populated areas?	yes	no
If yes, are local government or state emergency service personnel with access to established public warning systems and authority to use them involved in planning for public notifications?	yes	no
For in situ burning on land, has the landowner and occupant been consulted?	yes	no
Is in situ burn smoke expected to pass into a Class I airshed?	yes	no
Is Level 1 public notification implemented in Green Zone?	yes	no
Are Level 2 medical alert to people with existing conditions, and Level 3 warning notification, and in-place sheltering, implemented in Yellow Zone?	yes	no
Is Level 4 emergency notification and temporary evacuation implemented?	yes	no

ON-SCENE COORDINATORS' REVIEW CHECKLIST
In Situ Burning Guidelines for Alaska

Trial Burn:

Is the trial burn's smoke plume comparable to the predicted smoke plume in size, direction of drift, and dispersion, thus validating the predicted safe downwind distance? yes no

If no, then expand the safe distance to a circle centered at the burn with a radius of 3 miles extending in all directions. Is the safe distance expanded? yes no

Authorization and Conditions:

The on-scene coordinators' decision based on review (check one):

____ Do not conduct in situ burning.

____ In situ burning may be conducted in limited or selected areas (see attached chart).

____ In situ burning may be conducted over the limited period of ____ day(s).

____ In situ burning may be conducted as requested in the application.

Conditions:

1. The burn operations team will visually monitor the smoke plume.
2. The burn operations team will collect the burn residue in accordance with in situ burn plan that considered all potential methods of collection.
3. Public notification.
4. Other site-specific conditions of authorization: ____________________________________

Signature of Federal On-Scene Coordinator	Printed Name of Federal On-Scene Coordinator	Date and Time
Signature of State On-Scene Coordinator	Printed Name of State On-Scene Coordinator	Date and Time

Prepared By: ____________________ ICS Position: ___________________ Phone: ____________

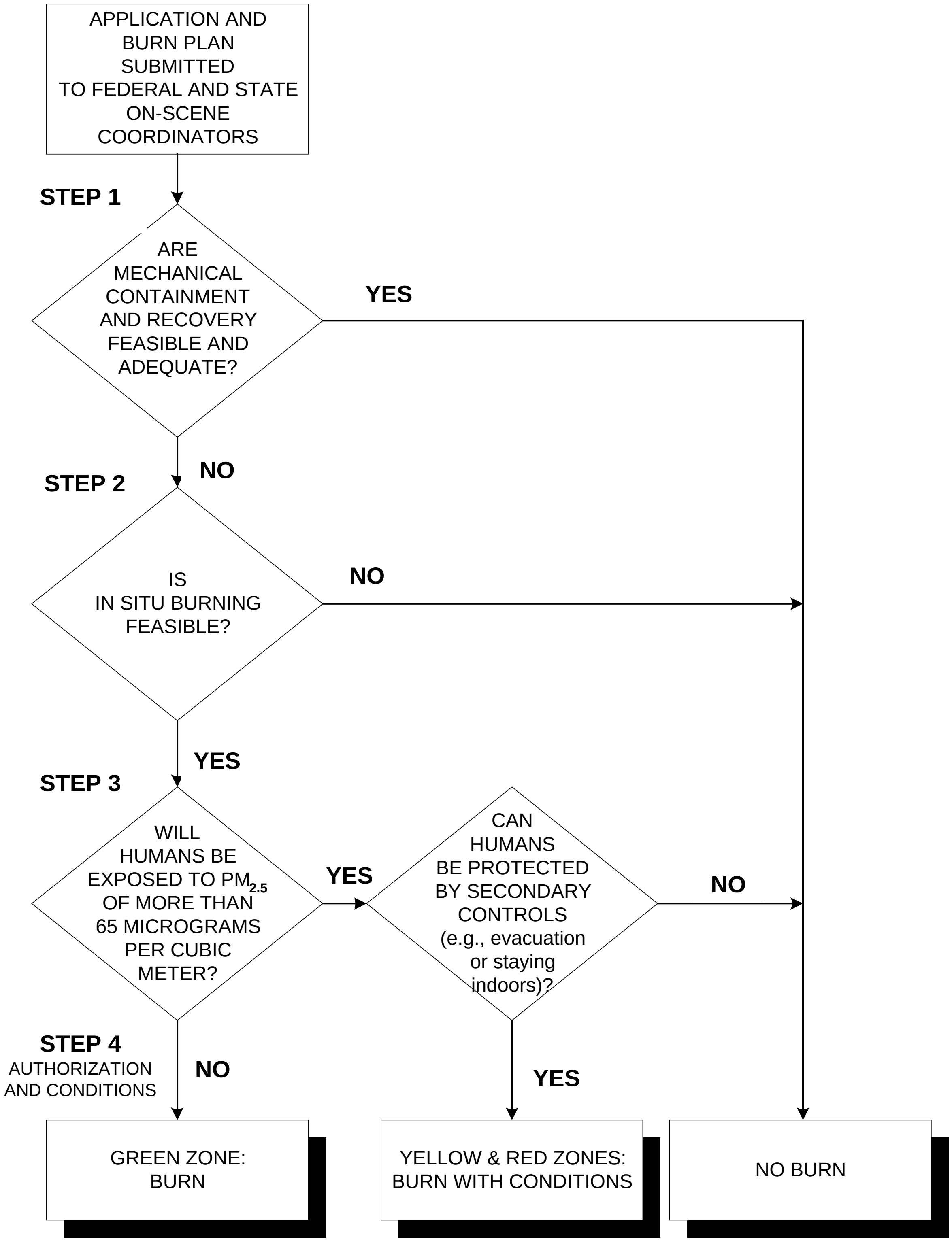
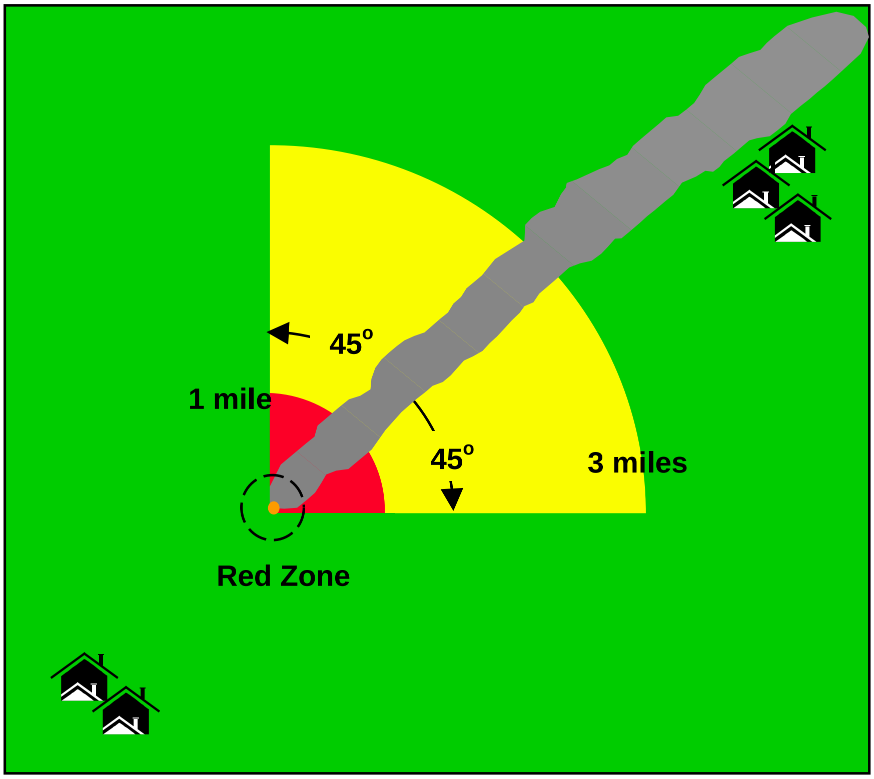
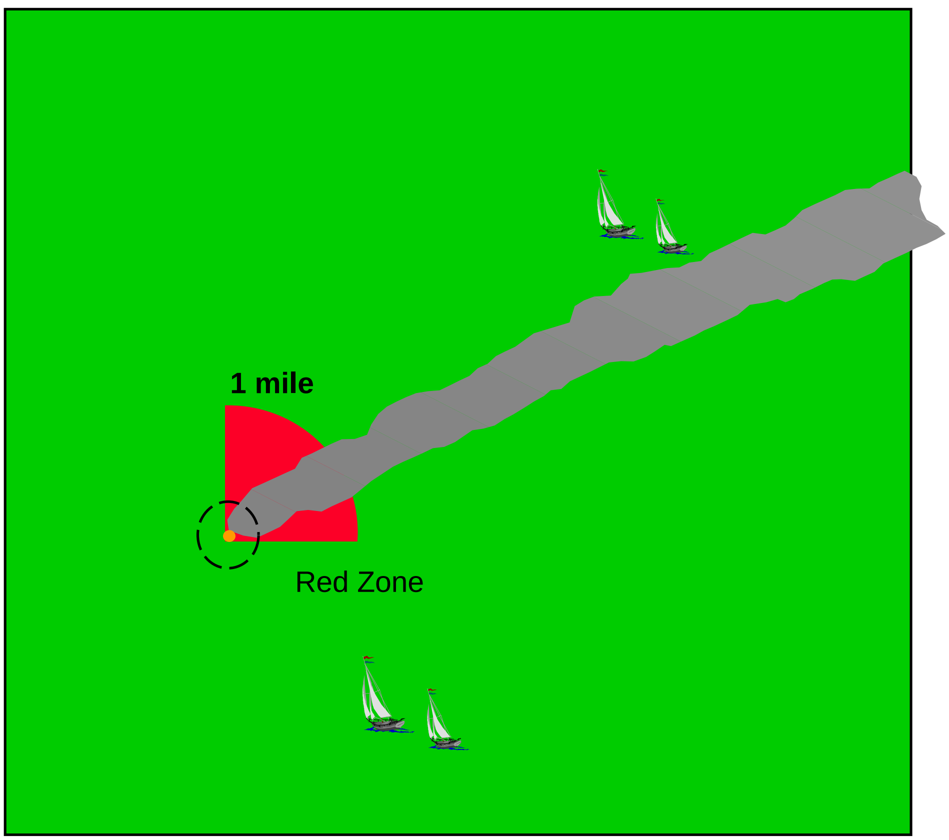


Figure 5. In Situ Burning Decision-Making Process



6A: Zones for in situ burns on populated flat terrain, or on water within 3 miles of shore.



6B: Zones for in situ burns on water more than 3 miles from shore.

Figure 6. In Situ Burn Zones

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